



RESEARCH MEMORANDUM

VAPOR PRESSURES OF CONCENTRATED NITRIC ACID SOLUTIONS IN
THE COMPOSITION RANGE 83 TO 97 PERCENT NITRIC ACID
0 TO 6 PERCENT NITROGEN DIOXIDE, 0 TO 15 PERCENT
WATER, AND IN THE TEMPERATURE RANGE 20° TO 80° C

By A. B. McKeown and Frank E. Belles

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
September 17, 1953

LIBRARY COPY

OCT 14 1958

LIBRARY, NASA
LANGLEY FIELD, VIRGINIA

NACA RM E53G08

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

VAPOR PRESSURES OF CONCENTRATED NITRIC ACID SOLUTIONS IN THE
 COMPOSITION RANGE 83 TO 97 PERCENT NITRIC ACID, 0 TO 6 PERCENT
 NITROGEN DIOXIDE, 0 TO 15 PERCENT WATER, AND IN THE
 TEMPERATURE RANGE 20° TO 80° C

By A. B. McKeown and Frank E. Belles

SUMMARY

Total vapor pressures were measured for 28 acid mixtures of the ternary system nitric acid, nitrogen dioxide, and water within the temperature range 20° to 80° C and within the composition range 83-97 percent nitric acid, 0-6 percent nitrogen dioxide, and 0-15 percent water. The ullage of the apparatus used for the measurements was 0.65.

Ternary diagrams showing isobars as a function of composition of the system, $\text{NO}_2\text{-H}_2\text{O-HNO}_3$, were constructed from experimental and interpolated data for the temperatures 25°, 40°, and 60° C and are presented herein.

INTRODUCTION

Concentrated solutions of nitric acid containing oxides of nitrogen are commonly used in many propellant and chemical applications. Certain properties, such as vapor pressures and boiling points, are therefore of considerable interest. A recent literature survey made at this laboratory indicated that data are lacking on vapor pressures of ternary systems of nitric acid, water, and nitrogen dioxide at temperatures greater than 25° C.

Vapor pressures of binary systems of nitric acid and water have been determined experimentally for the temperature range 0° to 125° C (refs. 1, 2, and 3). The vapor pressure of pure nitric acid has been calculated from thermodynamic data on the assumption that the fugacity and vapor pressure are equal (ref. 4). Total vapor pressures for the ternary system nitric acid, water, and nitrogen dioxide have been measured at the temperatures 0°, 12.5°, and 25° C for anhydrous, 19 N (82 weight percent), and 16 N (71 weight percent) nitric acid diluted with varying amounts of nitrogen dioxide (ref. 5).

CM-1

To obtain more complete vapor pressure data, an investigation was made at the NACA Lewis laboratory to determine the total vapor pressures of the ternary system nitric acid, water, and nitrogen dioxide within the temperature range 20° to 80° C and within the composition range 83 to 97 percent nitric acid, 0 to 15 percent water, and 0 to 6 percent nitrogen dioxide. The experiments were planned with a view toward establishing a relation between total vapor pressure and composition of the acid solution.

The total vapor pressures of 28 acid mixtures are presented herein. The data were obtained by use of an isoteniscope.

APPARATUS

A diagrammatic sketch of the equipment is shown in figure 1. The apparatus consisted of an isoteniscope, a mercury manometer, a thermometer, a vacuum system, and a heat control unit.

Isoteniscope. - An isoteniscope was used for the vapor pressure measurements in order to separate the acid vapors from the corrodible parts of the vacuum system. The instrument was a Smith and Menzies type, modified by the addition of a reservoir, to contain the separating fluid during the degasification procedure (ref. 6, p. 439). The isoteniscope was made of pyrex glass and was attached to the vacuum system by means of a ground-glass spherical joint. The acid chamber of the isoteniscope (A in fig. 1) was attached to the U-tube by means of a ground-glass taper joint, lubricated with Halocarbon stopcock grease, which resisted attack by the acids. The acid chamber was filled with approximately 5 milliliters of acid during operation of the apparatus. The reservoir (B in fig. 1) was filled with approximately 10 milliliters of fluorocarbon (Fluorolube S), the separating fluid. The ullage of the isoteniscope, that is, the ratio of the vapor volume to vapor volume plus liquid sample volume, was approximately 0.65 under operating conditions.

Temperature control system. - The isoteniscope was maintained at specified temperatures by immersion in a 4000-milliliter transparent Dewar flask filled with water at a predetermined temperature. The water was heated in a separate constant-temperature bath and was circulated through the Dewar flask by a pump during experimental runs. The constant-temperature bath was heated by two 750-watt immersion-type heaters connected in series with an immersion-type thermostat, which controlled the temperature of the bath to $\pm 0.5^{\circ}$ C. The temperature of the liquid in the Dewar flask was measured by a calibrated thermometer that could be read to $\pm 0.2^{\circ}$ C.

PROCEDURE

Preparation of acid samples. - Acid samples were prepared by mixing aliquot portions of 99.8 percent HNO_3 , distilled H_2O , and a 33.1 percent by weight solution of NO_2 in HNO_3 . The 99.8 percent HNO_3 was prepared by the vacuum distillation of a mixture comprising two parts of concentrated sulfuric acid and three parts of commercial white fuming nitric acid (approximately 98 percent HNO_3) at a temperature of 10° to 15° C. The 33.1 percent solution of NO_2 in HNO_3 was prepared by passing gaseous NO_2 into 99.8 percent HNO_3 .

Degasification of acid sample. - Acid samples were degassed in the isoteniscope to remove absorbed carbon dioxide and air. Degasification was accomplished prior to the determination of vapor pressures by several repetitions of the following procedure: (1) the acid sample was frozen with liquid nitrogen; (2) air was evacuated from the isoteniscope; (3) the vacuum tap to the isoteniscope was closed; and (4) the sample was allowed to melt. In order to avoid the possibility of carbon dioxide being retained in the acid sample in the frozen state, an ethanol-water solution at a temperature of -95° to -100° C was used as a cooling medium in the final repetition of the degasification procedure.

Measurement of vapor pressures. - Following degasification, the vacuum tap was closed and the isoteniscope was removed from the vacuum system. With the sample still frozen, the fluorocarbon separating fluid was allowed to flow into the U-tube to approximately one-half the height of the U-tube. The liquid levels were marked as reference points for essentially equal pressures in both arms of the U-tube. The instrument was reattached to the vacuum system and vapor pressures were measured as follows: (1) water was circulated through the Dewar flask from the constant-temperature bath until the temperature was reached at which the first vapor pressure reading was to be taken; (2) as the pressure of the vapors in the acid chamber increased with rising temperature, the liquid in the arms of the U-tube was maintained at the reference levels by controlled admission of air into the vacuum system; (3) when no further pressure changes were observed, temperature and pressure readings were recorded. The air pressure required to balance the vapor pressure of the acid sample was read on an absolute manometer.

Pressure measurements were made in the same manner at successively higher temperatures. After the pressure reading at the highest temperature was taken, the acid sample was cooled to the initial temperature and another reading was taken to detect any pressure increase that might have occurred during the run due to the decomposition of the acid.

Pressure measurements were made at all temperatures within the time interval 20 to 30 minutes.

Acid analysis. - The acid samples were analyzed by the method of U. S. Air Force Specification No. 14104 with the exception that total acidity was determined by direct titration of the acid sample in water with NaOH solution. The NO_2 was determined by back-titration of the sample in $\text{Ce}(\text{NH}_4)_2(\text{SO}_4)_3$ solution with FeSO_4 . Water content was determined by the subtraction of the sum of the NO_2 content and HNO_3 content from 100 percent.

Acid analyses were made both on stock solutions and on samples taken from the isoteniscope after experimental runs. The acid analyses reported in table I are for stock solutions, inasmuch as fresh samples from stock solutions were used for each experimental run. The analyses in table I represent the average of two determinations for each sample.

RELIABILITY OF MEASUREMENTS

Accuracy of the apparatus. - The inherent accuracy of the apparatus was checked by comparison of the measured vapor pressures of benzene and distilled water with their values as reported in the literature. The experimental data and the literature values for the same temperature are presented in the following table:

Temperature, °C	Vapor pressure, mm Hg		Deviation, percent
	Experimental	Literature ^a	
Distilled water			
31.7	35.8	35.1	2.0
43.9	69.1	67.9	1.8
53.4	110.1	109.3	.7
59.1	145.0	143.2	1.3
			Av. 1.4
Benzene			
19.2	72.5	72.3	0.3
24.5	93.4	93.0	.4
30.7	120.8	123.0	-1.8
39.0	172.6	175.3	-1.5
			Av. 1.0

^aValues for water are from ref. 7 (table 9, p. 391);
values for benzene, from ref. 8.

From this table it appears that the experimental error associated with this apparatus is of the order of 1 to 1.5 percent.

Ullage effects. - The ullage of the isoteniscope used in this investigation was approximately 0.65 under operating conditions. For several samples the ullage was varied approximately 20 percent between the first run and the check run without measurable change in vapor pressure.

The vapor pressures measured by this apparatus are essentially due to the transfer of varying proportions of the constituents from the liquid to the vapor phase, which produces changes in the composition of the liquid remaining. Inasmuch as it is necessary to report vapor pressures as those in equilibrium with samples of composition determined by prior analysis, calculations were made by means of the ideal gas law to determine the maximum change in liquid composition that could take place by the transfer of components from the liquid to the vapor phase. As an extreme case, these calculations were based on the assumption that the vapor space was entirely occupied by the least abundant component of the liquid phase. For most of the samples, these calculations showed that the maximum amount of the component that could be transferred to the vapor phase was generally less than 5 percent of the total quantity of this component present in the original liquid sample. For samples containing 0.15 to 0.21 percent NO_2 , the calculations showed changes of approximately 50 percent of the NO_2 present in the liquid sample; however, the condition of these calculations was more severe than the condition encountered in actual practice, since vapor pressure is not due solely to one constituent of the mixture.

From the experimental evidence and the calculations just described, it was therefore concluded that ullage is not a significant source of error in these measurements. However, inasmuch as the effects of wide variations in ullage were not experimentally determined, the reader is cautioned against the indiscriminate application of the results to systems with ullage differing from 0.65.

Effects of decomposition and degasification. - As described earlier, the vapor pressure of each sample was measured twice at the initial temperature of the experimental run, once at the beginning of the run and once at the conclusion. Invariably, the second pressure was higher than the first, indicating that a certain amount of decomposition had taken place during the experimental run. The largest pressure increase experienced for all runs between the initial and final readings was 16.5 millimeters of mercury, and the average increase for all the experimental runs was 4.5 millimeters of mercury. Inasmuch as the amount of decomposition increases with both temperature and time, it is reasonable to expect that errors due to decomposition affect chiefly the higher vapor-pressure measurements, corresponding to higher temperatures and longer time intervals. By comparison of the pressure increases with the vapor pressures at the higher temperatures, it appears that errors in pressure measurements due to decomposition were on the average less than 3 percent of the measured pressures at the higher temperatures.

Further evidence, given in the following table, shows that change in composition of the acid due to decomposition and degasification is

small. The data in this table were obtained by analysis of two acid samples both before and after experimental runs.

Sample number	Analysis, percent by weight			
		HNO ₃	NO ₂	H ₂ O
17	Stock solution	91.10	2.60	6.30
	After experimental run number 1	90.81	2.75	6.44
	After experimental run number 2	91.19	2.58	6.23
12	Stock solution	95.10	2.16	2.74
	After experimental run number 1	95.16	2.09	2.75
	After experimental run number 2	95.03	2.03	2.94

RESULTS AND DISCUSSION

The measured vapor pressures for 28 acid samples are presented in table I. Vapor pressures were not measured for some of the acids at temperatures above 70° C since limiting features of the apparatus made it impossible to measure vapor pressures above 1 atmosphere.

Figure 2 is a logarithmic plot of total vapor pressure of the acid versus vapor pressure of water (ref. 7) at equal temperatures (methods from refs. 9 and 10). This figure is a plot of the raw data for all the acid samples. No special significance is attached to the way the samples are grouped in the figure. When great accuracy is not needed, the vapor pressures of the various acids above 70° C may be obtained by extrapolation of the curves in this figure.

Figure 3 is presented to show the effect of variation of composition of the acid sample on vapor pressure at temperatures of 25° C, 40° C, and 60° C, respectively. An attempt was made to prepare samples in sets of approximately constant NO₂ concentration for the purpose of relating composition of the acid with vapor pressure at specific temperatures. These concentrations were 0.15-0.21, 1.07-1.24, 2.02-2.28, 2.48-2.70, 3.48-3.60, and 5.30-5.63 percent NO₂, with varying amounts of HNO₃ and H₂O. In figure 3 vapor pressure is plotted against weight percent HNO₃ for the NO₂ concentrations mentioned. Vapor pressure values were obtained from the smoothed curves of the pressure-temperature data of table I for each acid composition. These data indicate that, within the composition range studied, an increase in total vapor pressure is produced by a

decrease in HNO_3 content for acids containing 2.0 percent NO_2 or more. For acids containing less than 1.25 percent NO_2 an opposite effect is shown.

Ternary diagrams showing isobars as a function of the composition of the system $\text{NO}_2\text{-H}_2\text{O-HNO}_3$ are presented for the temperatures 25° , 40° , and 60° C in figure 4. These diagrams were constructed both from interpolated vapor pressure values taken from figure 3 and from experimental data points. While subject to minor inaccuracies due to the manner of their construction, these diagrams can be used to estimate the vapor pressure, at 25° , 40° , and 60° C, of any sample within the range of composition covered by the ternary plots. Such estimates at two different temperatures may then be plotted as the logarithm of the vapor pressure of the acid against the logarithm of the vapor pressure of water at equal temperature. A straight line drawn through these two points gives good predictions of the vapor pressures at other temperatures in the range 20° to 80° C.

Vapor pressures of 62.1 millimeters of mercury and 100.5 millimeters of mercury have been reported for anhydrous nitric acids containing 0 and 6 weight percent NO_2 , respectively, at 25° C (ref. 5). These data correspond closely to the vapor pressures predicted by figure 4(a) (65 mm Hg and 89 mm Hg) for these compositions at 25° C.

The calculated vapor pressures of pure HNO_3 are reported in reference 4 as 62.5 millimeters of mercury, 133 millimeters of mercury, and 317 millimeters of mercury at the temperatures, 25° , 40° , and 60° C, respectively. These data are shown in figure 3 for the purpose of comparison with the values obtained by extrapolation of the 0.15-0.21 percent NO_2 curve to 100 percent HNO_3 . Vapor pressures obtained by this extrapolation were 65.5 millimeters of mercury at 25° C, 141 millimeters of mercury at 40° C, and 344 millimeters of mercury at 60° C.

SUMMARY OF RESULTS

Total vapor pressures were measured for concentrated acids of the system, $\text{NO}_2\text{-H}_2\text{O-HNO}_3$ within the temperature range 20° to 80° C. Results of the investigation may be summarized as follows:

1. For acids containing 2.0 percent NO_2 or more, an increase in HNO_3 content resulted in a decreased total pressure. For acids containing 1.2 percent NO_2 or less, an increase in HNO_3 content resulted in an increased total pressure.

2. A straight line was obtained throughout the temperature range 20° to 80° C for the logarithmic plot of vapor pressure of the acid versus vapor pressure of water at equal temperature.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, July 10, 1953

REFERENCES

1. Taylor, Guy B.: Vapor Pressure of Aqueous Solutions of Nitric Acid. Ind. and Eng. Chem., vol. 17, no. 6, June 1925, pp. 633-635.
2. Wilson, G. L., and Miles, F. D.: The Partial Pressures of Nitric Acid-Water Mixtures from 0°-20° C. Trans. Faraday Soc., vol. 36, 1940, pp. 356-363.
3. Burdick, Charles L., and Freed, E. Stanley: The Equilibrium Between Nitric Oxide, Nitrogen Peroxide and Aqueous Solution of Nitric Acid. Jour. Am. Chem. Soc., vol. XLIII, no. 3, Mar. 1921, pp. 518-530.
4. Egan, Edward P., Jr.: Vapor Pressure of Liquid Nitric Acid. Ind. and Eng. Chem., vol. 37, no. 3, Mar. 1945, pp. 303-304.
5. Klemenc, Alfons, und Rupp, Johann: Zur Kenntnis der Saltpetersäure. VI. Die Totaldampfdrucke der Lösungen von Stickstoffdioxid in hochkonzentrierter bis absoluter Saltpetersäure und die entsprechenden Dichten. Zeitschr. f. anorg. u. allg. Chem., Bd. 194, Heft 1, Nov. 18, 1930, pp. 51-72.
6. Glasstone, Samuel: Text-Book of Physical Chemistry. D. Van Nostrand Co., Inc., (New York), 1940.
7. Perry, John H., ed.: Chemical Engineer's Handbook. Second ed., McGraw-Hill Book Co., Inc., 1941.
8. Rossini, Frederick D., et al.: Selected Values of Properties of Hydrocarbons. Circular C461, Nat. Bur. Standards, Nov. 1947.
9. Othmer, Donald F.: Correlating Vapor Pressure and Latent Heat Data. Ind. and Eng. Chem., vol. 32, no. 6, June 1940, pp. 841-856.
10. Cox, Edwin R.: Pressure-Temperature Chart for Hydrocarbon Vapors. Ind. and Eng. Chem., vol. 15, no. 6, June 1923, pp. 592-593.

TABLE I. - VAPOR PRESSURES OF VARIOUS NITRIC ACID, NITROGEN DIOXIDE, AND WATER MIXTURES

[Mixture, 0.65; all temperatures are in °C; all pressures are in mm Hg.]



Sample number	Analysis of stock solution			Run number 1										Run number 2									
	HNO ₃ , percent	NO ₂ , percent	H ₂ O, percent	Temperature	21.0	24.0	32.3	42.0	64.1	75.2	27.7	34.0	40.8	51.8	75.9	-----	-----	-----	-----	-----	-----	-----	-----
1	94.40	0.18	5.42	Vapor pressure	43.1	50.1	75.0	121.0	310.0	486.8	64.5	87.0	116.5	185.0	454.0	-----	-----	-----	-----	-----	-----	-----	-----
2	92.07	0.15	7.78	Temperature	21.0	27.0	37.0	48.0	61.0	-----	24.4	31.0	38.5	61.2	76.4	-----	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	37.8	51.0	85.0	149.5	289.5	-----	45.5	61.5	89.0	247.5	430.0	-----	-----	-----	-----	-----	-----	-----	-----
3	89.32	0.21	10.47	Temperature	25.8	35.0	44.0	54.9	64.4	77.8	24.9	30.1	40.5	50.5	61.4	72.2	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	56.3	65.1	97.0	159.0	256.8	384.0	38.6	51.0	65.0	139.0	211.0	326.8	-----	-----	-----	-----	-----	-----	-----
4	96.83	0.16	3.01	Temperature	18.0	25.0	32.1	41.5	51.4	58.0	17.9	25.0	30.0	34.0	59.0	-----	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	39.8	58.1	84.0	131.8	210.2	281.3	40.1	58.0	76.5	92.5	434.9	-----	-----	-----	-----	-----	-----	-----	-----
5	95.47	0.74	3.79	Temperature	20.5	25.9	34.4	44.9	54.0	64.2	21.3	26.0	35.2	45.8	-----	-----	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	48.5	57.0	99.5	158.9	265.0	406.0	52.6	67.0	107.8	184.0	-----	-----	-----	-----	-----	-----	-----	-----	-----
6	84.38	1.20	14.42	Temperature	18.9	25.2	29.9	36.7	57.1	76.5	25.2	32.8	43.0	53.5	65.9	72.8	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	44.0	65.0	82.1	126.8	302.5	654.6	64.5	96.2	159.0	287.8	401.5	574.5	-----	-----	-----	-----	-----	-----	-----
7	89.62	1.24	9.14	Temperature	16.7	25.0	29.0	59.1	48.8	76.4	25.1	35.4	46.0	57.1	65.8	71.1	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	44.6	57.5	78.1	129.3	208.2	668.9	62.0	106.5	179.9	305.7	401.7	535.3	-----	-----	-----	-----	-----	-----	-----
8	92.14	1.07	6.79	Temperature	19.3	25.7	39.0	48.4	58.8	75.5	19.4	25.2	34.1	42.9	49.0	69.5	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	48.3	62.4	135.0	212.8	335.8	667.5	49.1	76.9	105.5	164.5	215.2	518.2	-----	-----	-----	-----	-----	-----	-----
9	91.75	1.32	6.95	Temperature	24.0	29.9	39.3	54.9	65.2	74.4	19.5	30.0	40.9	47.0	72.5	-----	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	61.1	85.2	156.2	266.1	412.0	652.0	47.5	65.8	146.1	199.0	600.8	-----	-----	-----	-----	-----	-----	-----	-----
10	89.50	2.22	8.28	Temperature	22.0	29.1	39.0	48.8	58.2	68.3	19.0	25.0	28.8	34.1	43.7	62.0	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	67.5	100.0	160.0	255.8	395.6	599.9	57.8	71.8	95.3	129.8	214.2	449.8	-----	-----	-----	-----	-----	-----	-----
11	85.96	2.02	12.02	Temperature	24.1	29.4	43.9	50.8	59.4	70.5	19.1	25.0	32.6	40.9	48.0	67.0	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	75.0	99.3	210.5	298.0	452.9	679.1	65.5	70.0	116.7	176.7	255.0	586.2	-----	-----	-----	-----	-----	-----	-----
12	95.10	2.16	2.74	Temperature	24.3	29.3	39.0	49.1	59.4	68.4	18.8	29.5	35.0	45.1	59.4	66.3	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	71.5	91.5	151.5	252.0	401.7	595.7	61.3	92.2	124.8	206.3	400.9	547.4	-----	-----	-----	-----	-----	-----	-----
13	91.00	2.28	5.72	Temperature	25.9	32.4	39.0	49.8	59.5	69.4	19.0	25.0	29.4	44.0	54.0	64.2	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	85.4	119.0	167.2	276.5	432.2	654.0	59.7	73.9	105.2	212.3	343.0	524.8	-----	-----	-----	-----	-----	-----	-----
14	95.96	2.48	3.58	Temperature	19.0	25.5	35.9	51.4	63.9	72.4	16.0	19.0	27.0	35.2	40.8	71.5	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	52.0	67.0	118.9	209.0	305.2	470.5	44.8	52.6	82.3	128.3	169.6	704.3	-----	-----	-----	-----	-----	-----	-----
15	94.31	2.60	3.09	Temperature	24.0	29.2	38.5	49.8	58.9	69.3	20.3	29.5	34.0	43.0	51.6	64.3	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	75.0	98.4	158.0	276.7	425.9	654.8	60.8	99.5	125.0	198.7	299.5	534.7	-----	-----	-----	-----	-----	-----	-----
16	85.03	2.70	12.27	Temperature	24.0	29.0	41.0	49.0	59.2	70.7	18.9	24.2	30.2	37.8	49.0	68.4	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	77.8	102.6	180.5	282.0	447.0	715.8	55.8	75.8	106.6	159.4	280.7	689.0	-----	-----	-----	-----	-----	-----	-----
17	91.10	2.60	6.30	Temperature	19.5	25.5	29.1	36.5	48.7	60.2	23.0	29.1	40.2	49.1	86.8	67.5	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	57.0	72.5	99.8	144.7	266.6	444.0	71.0	98.5	175.0	271.9	388.8	609.4	-----	-----	-----	-----	-----	-----	-----
18	93.46	3.58	2.96	Temperature	22.1	26.5	35.9	45.2	55.1	66.4	18.1	31.2	41.5	49.9	55.8	70.0	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	75.0	88.8	148.8	238.0	351.0	629.2	62.4	121.0	199.5	305.8	418.5	738.1	-----	-----	-----	-----	-----	-----	-----
19	86.59	3.54	9.87	Temperature	18.8	26.1	39.1	47.5	55.0	68.1	20.9	32.2	36.9	50.5	60.5	67.4	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	75.6	107.7	199.8	299.1	423.0	726.0	82.7	145.8	179.7	342.8	529.4	705.4	-----	-----	-----	-----	-----	-----	-----
20	91.03	3.48	5.49	Temperature	16.0	18.2	30.6	39.0	49.2	59.2	18.5	25.8	34.5	44.7	56.2	68.5	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	55.8	67.9	119.0	179.0	298.6	483.4	67.1	92.2	144.0	239.4	396.0	594.7	-----	-----	-----	-----	-----	-----	-----
21	85.66	3.60	12.74	Temperature	19.0	30.9	39.0	46.0	57.5	62.2	18.8	23.7	30.2	37.0	51.6	63.5	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	68.6	130.5	200.0	283.9	479.4	592.5	68.7	91.6	129.8	184.7	374.3	625.1	-----	-----	-----	-----	-----	-----	-----
22	84.26	5.32	10.42	Temperature	22.7	26.6	37.5	47.2	59.2	65.2	19.9	27.2	33.2	42.1	52.2	61.9	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	91.2	118.0	206.6	346.5	593.0	715.0	81.9	123.5	171.5	269.0	442.5	691.0	-----	-----	-----	-----	-----	-----	-----
23	89.80	5.50	4.70	Temperature	21.8	29.9	39.1	48.4	56.0	65.3	20.0	28.9	35.9	44.0	52.8	66.3	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	78.2	121.8	202.8	323.0	460.5	700.5	72.5	104.0	168.4	261.2	401.0	737.7	-----	-----	-----	-----	-----	-----	-----
24	91.00	5.63	3.37	Temperature	22.1	27.1	35.0	39.8	53.0	60.7	17.5	20.7	33.0	36.8	45.0	62.5	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	78.4	104.4	155.7	200.0	395.8	559.1	60.3	71.8	142.8	174.2	241.5	606.1	-----	-----	-----	-----	-----	-----	-----
25	86.97	5.30	7.75	Temperature	23.1	30.0	34.5	40.8	55.2	64.0	21.1	29.0	37.6	50.2	62.9	-----	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	95.0	138.7	174.2	240.2	488.8	715.0	86.9	130.5	205.5	366.2	678.0	-----	-----	-----	-----	-----	-----	-----	-----
26	92.70	5.46	1.84	Temperature	24.3	29.4	35.1	44.7	54.8	63.9	19.2	24.0	29.7	34.8	40.7	66.1	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	89.7	118.0	180.1	262.9	430.3	658.7	67.5	88.6	120.6	187.6	213.6	721.0	-----	-----	-----	-----	-----	-----	-----
27	85.82	5.61	10.57	Temperature	24.8	28.5	34.0	47.0	54.0	62.1	19.0	32.5	39.0	49.0	53.9	59.1	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	114.2	140.0	186.0	359.2	506.1	716.3	79.8	168.3	237.7	391.7	491.6	821.8	-----	-----	-----	-----	-----	-----	-----
28	90.50	6.12	3.33	Temperature	22.6	34.4	41.0	48.8	54.5	-----	20.1	23.9	28.8	38.0	43.7	63.4	-----	-----	-----	-----	-----	-----	-----
				Vapor pressure	91.6	168.1	232.8	310.5	450.0	-----	78.2	98.4	124.3	196.2	264.0	681.0	-----	-----	-----	-----	-----	-----	-----

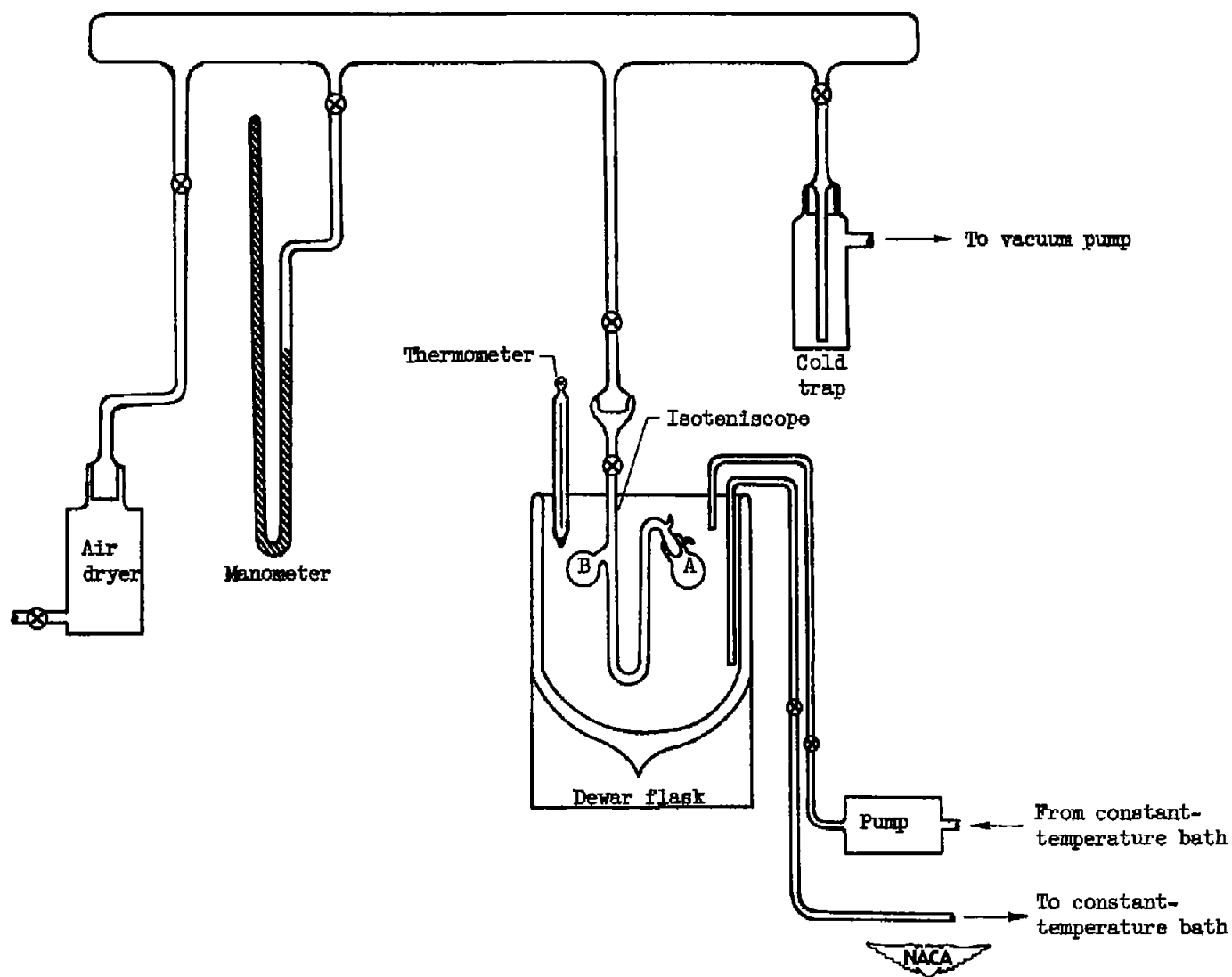
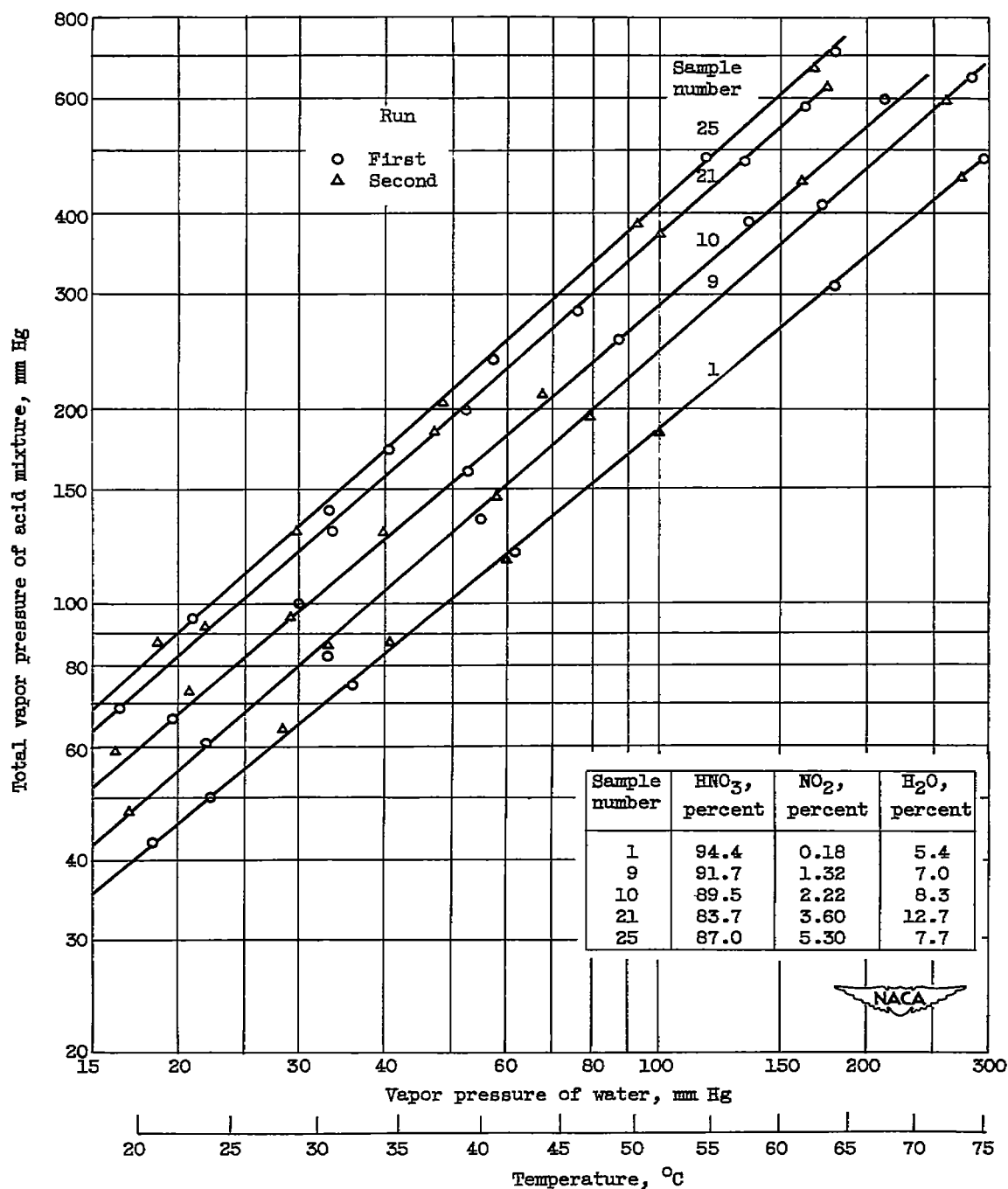


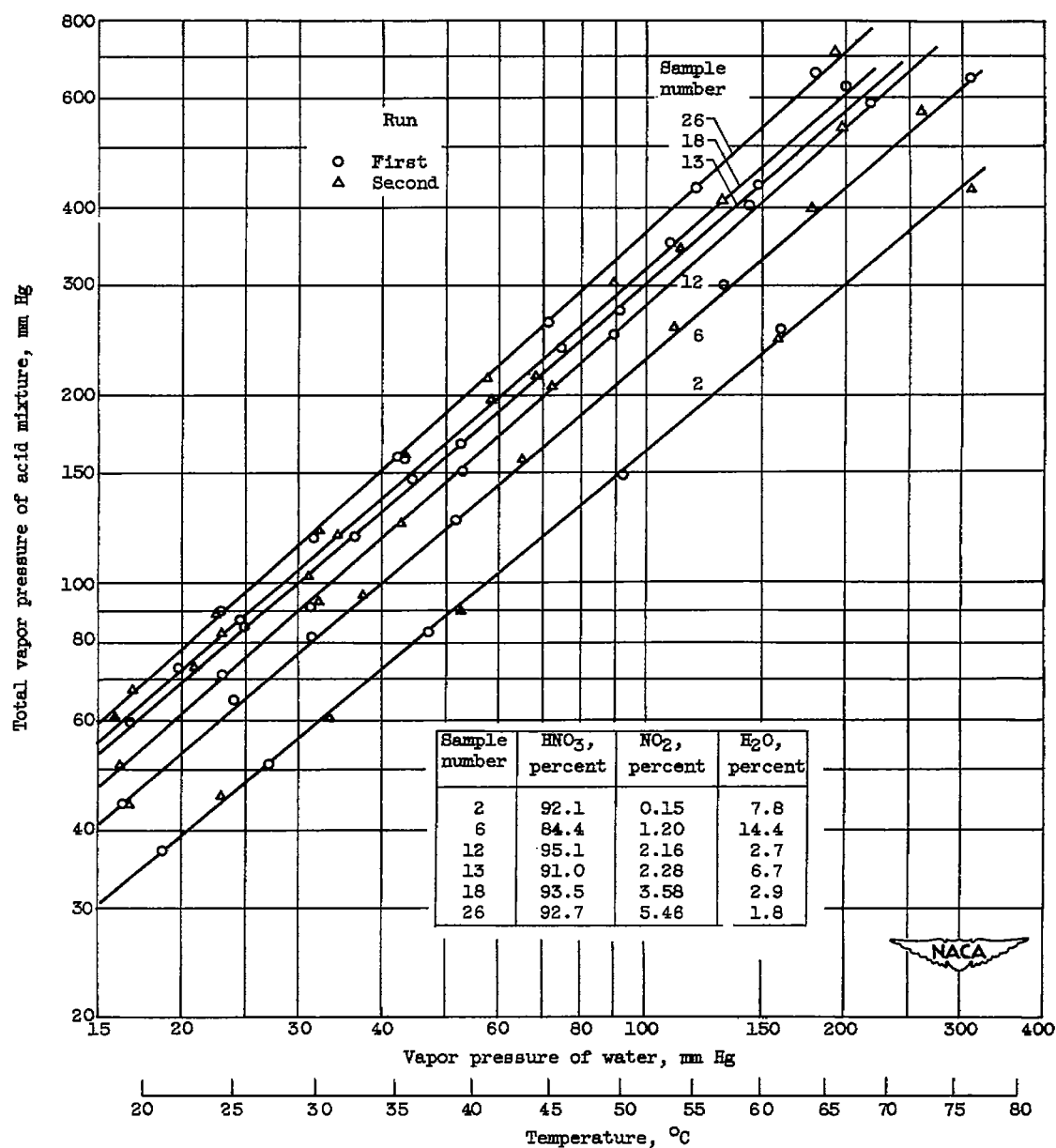
Figure 1. - Schematic diagram of vapor-pressure apparatus.

CM-2 back



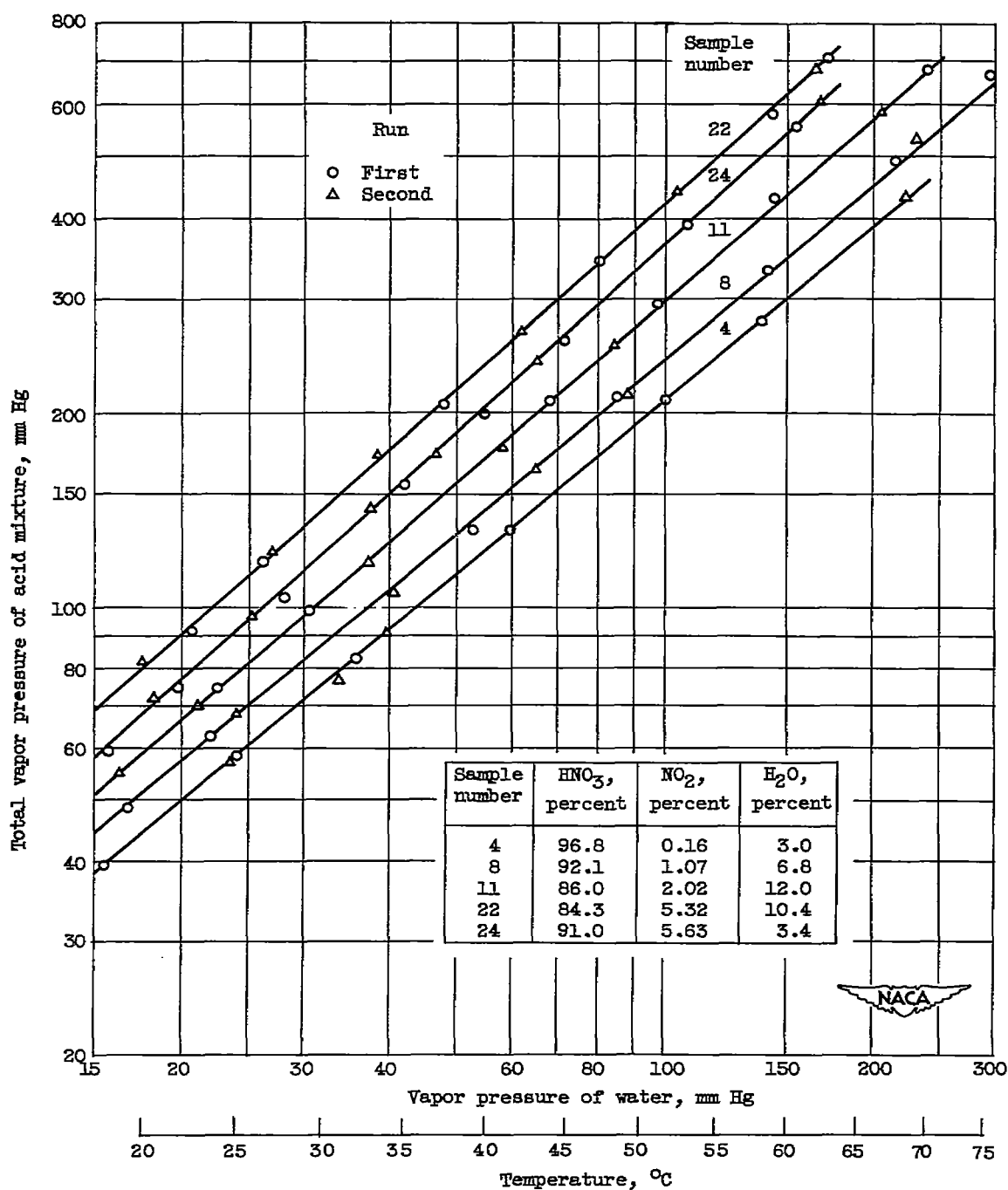
(a) Sample numbers 1, 9, 10, 21, and 25.

Figure 2. - Cox-Othmer plot of total vapor pressures of nitric acid solutions. Ullage, 0.65.



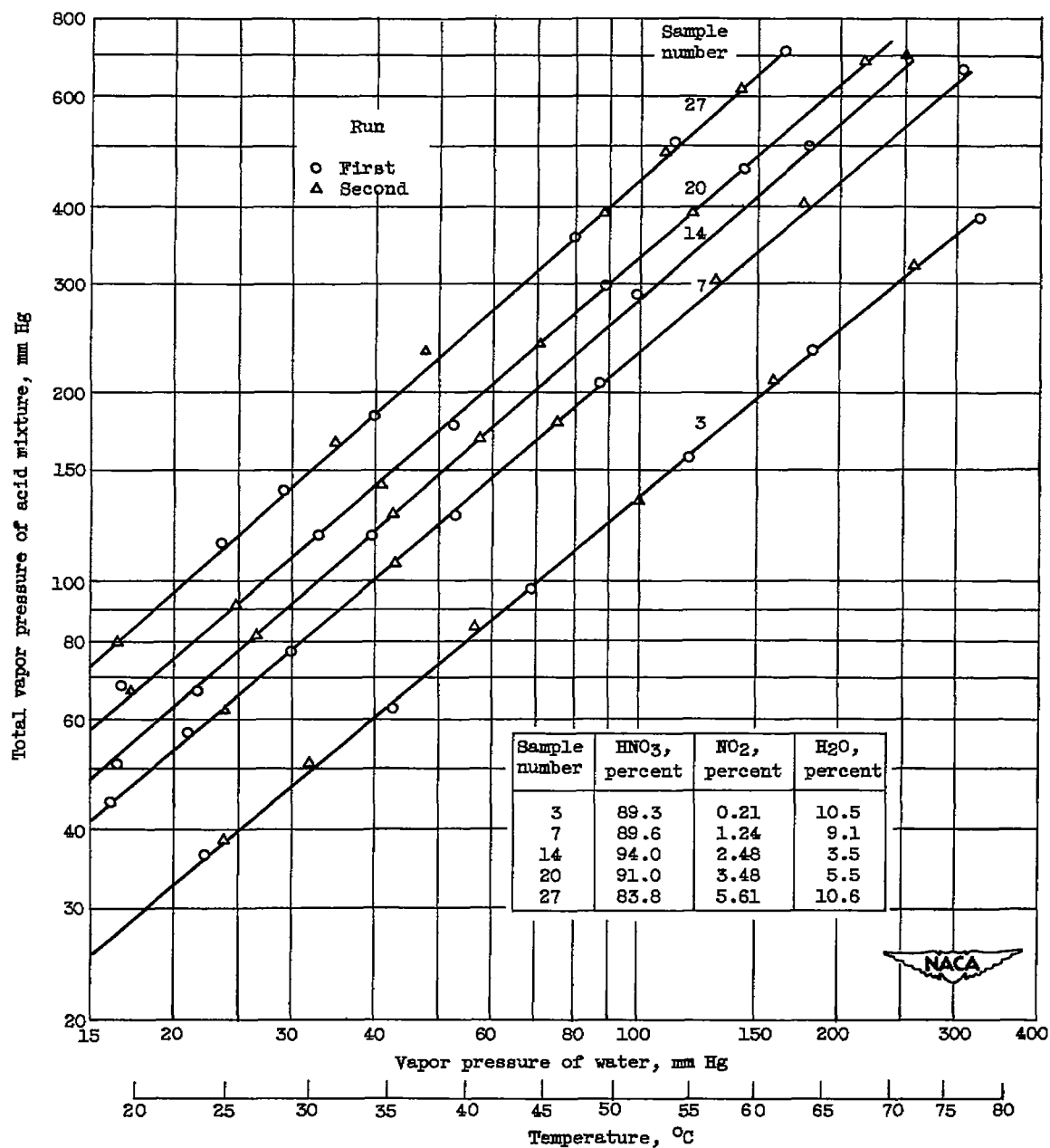
(b) Sample numbers 2, 6, 12, 13, 18, and 26.

Figure 2. - Continued. Cox-Othmer plot of total vapor pressures of nitric acid solutions. Ullage, 0.65.



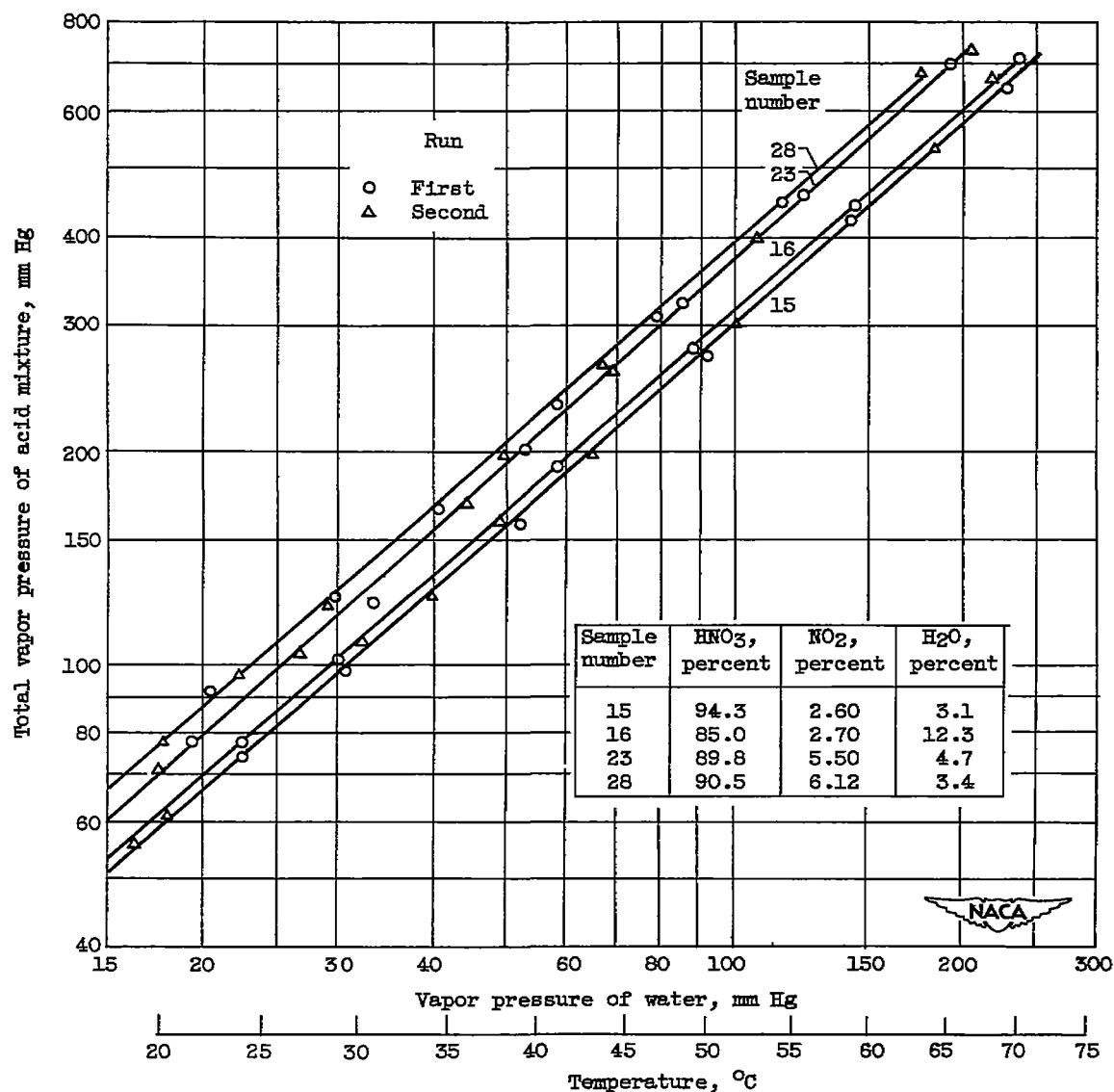
(c) Sample numbers 4, 8, 11, 22, and 24.

Figure 2. - Continued. Cox-Othmer plot of total vapor pressures of nitric acid solutions. Ullage, 0.65.



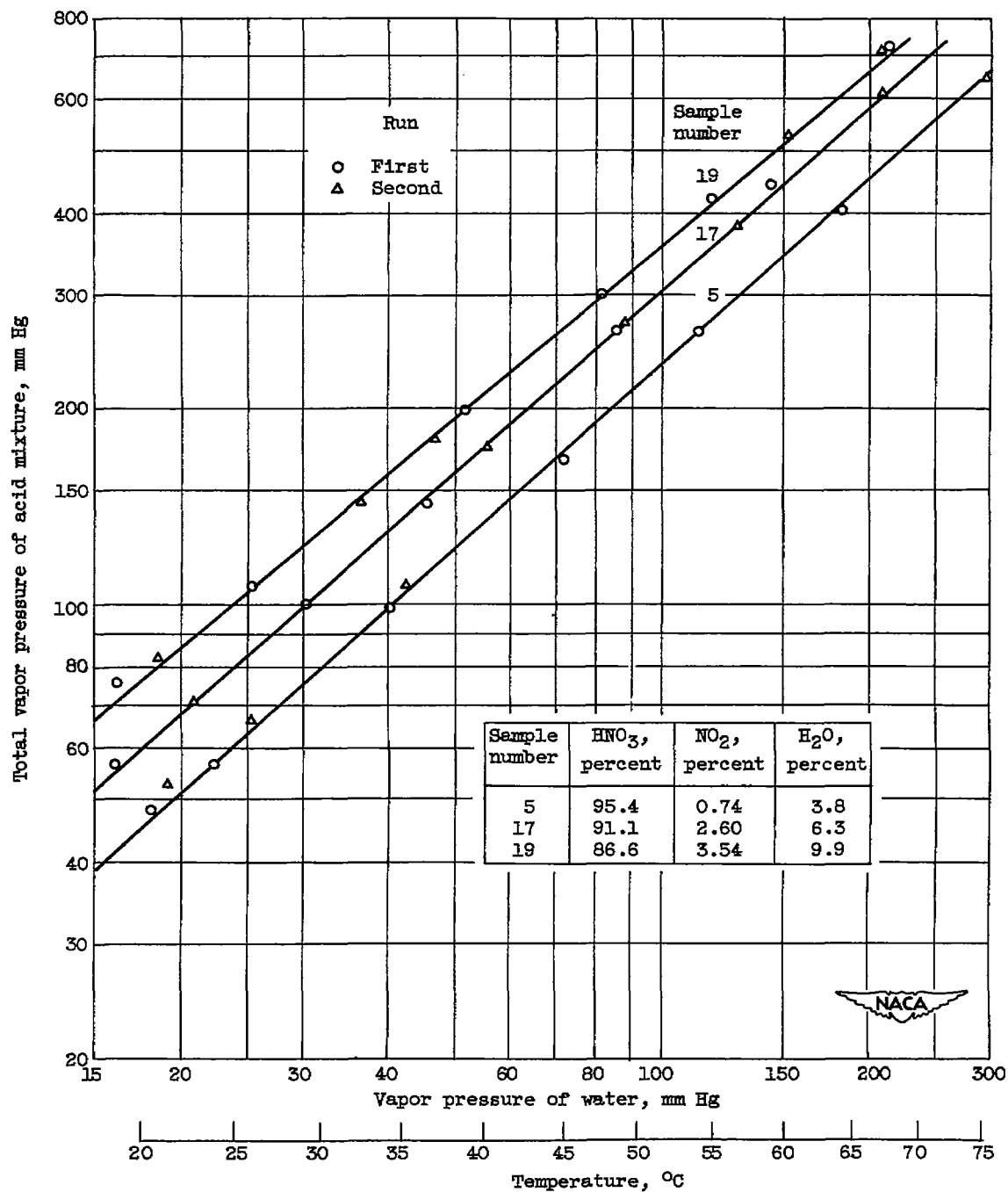
(d) Sample numbers 3, 7, 14, 20, and 27.

Figure 2. - Continued. Cox-Othmer plot of total vapor pressures of nitric acid solutions. Ullage, 0.65.



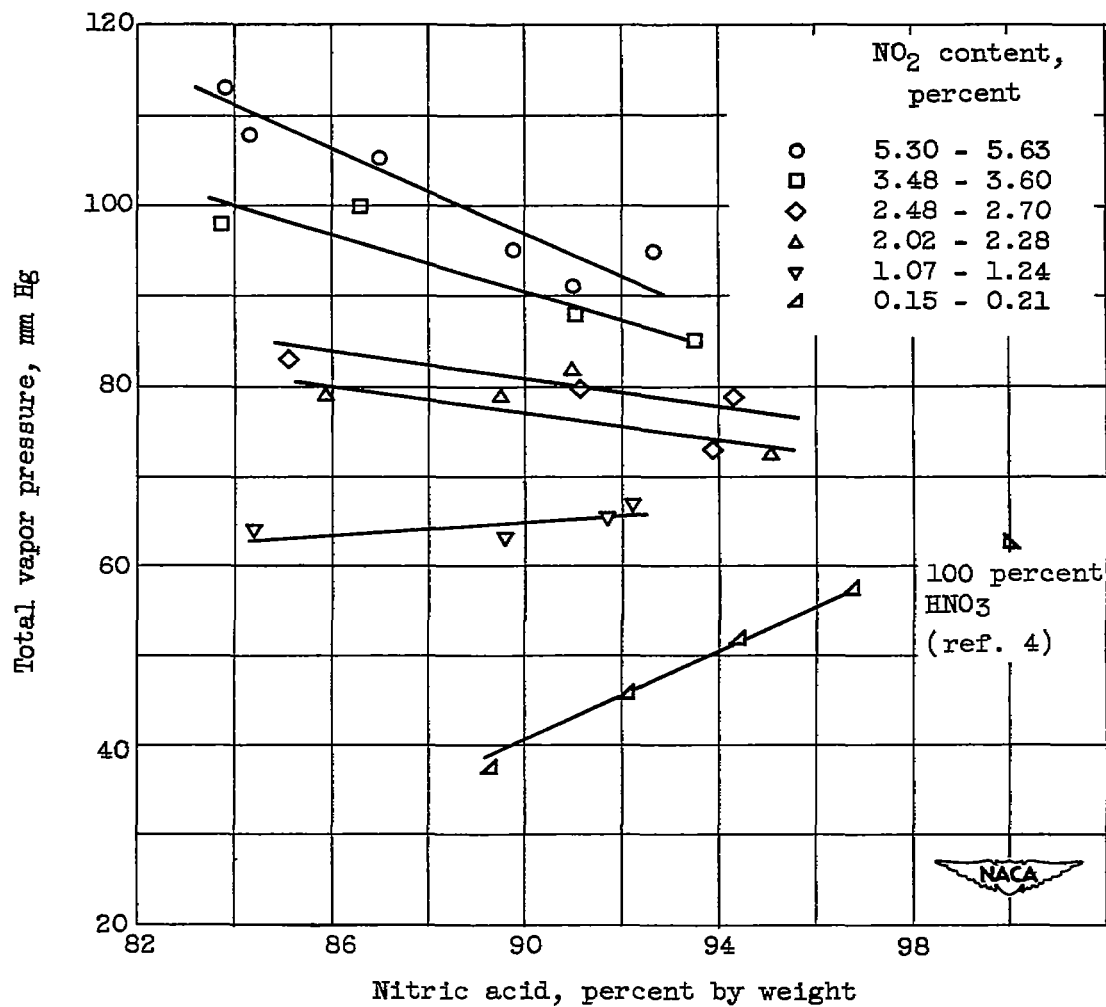
(e) Sample numbers 15, 16, 23, and 28.

Figure 2. - Continued. Cox-Othmer plot of total vapor pressures of nitric acid solutions. Ullage, 0.65.



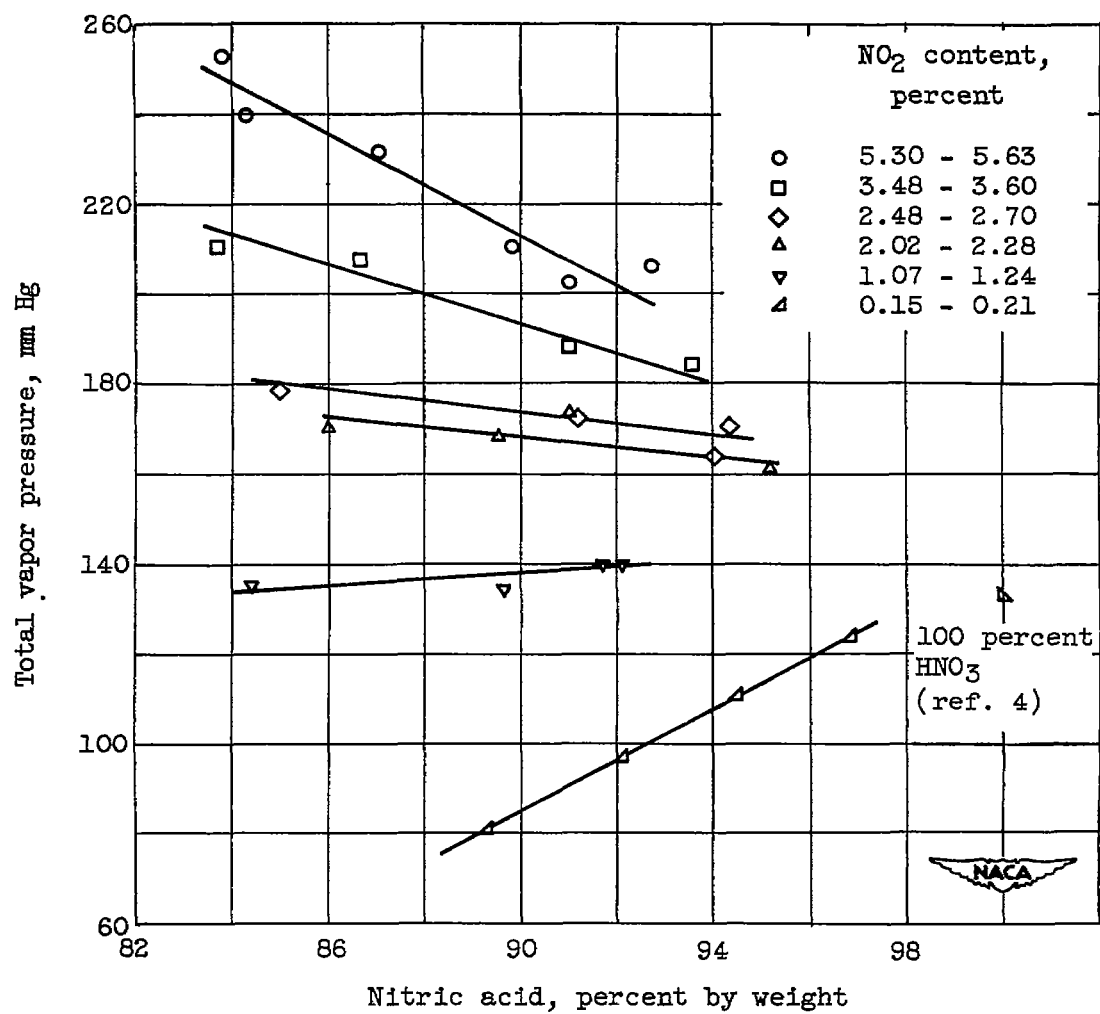
(f) Sample numbers 5, 17, and 19.

Figure 2. - Concluded. Cox-Othmer plot of total vapor pressures of nitric acid solutions. Ullage, 0.65.



(a) Temperature, 25° C.

Figure 3. - Variation of total vapor pressure of nitric acid solutions with composition. Ullage, 0.65.



(b) Temperature, 40° C.

Figure 3. - Continued. Variation of total vapor pressure of nitric acid solutions with composition. Ullage, 0.65.

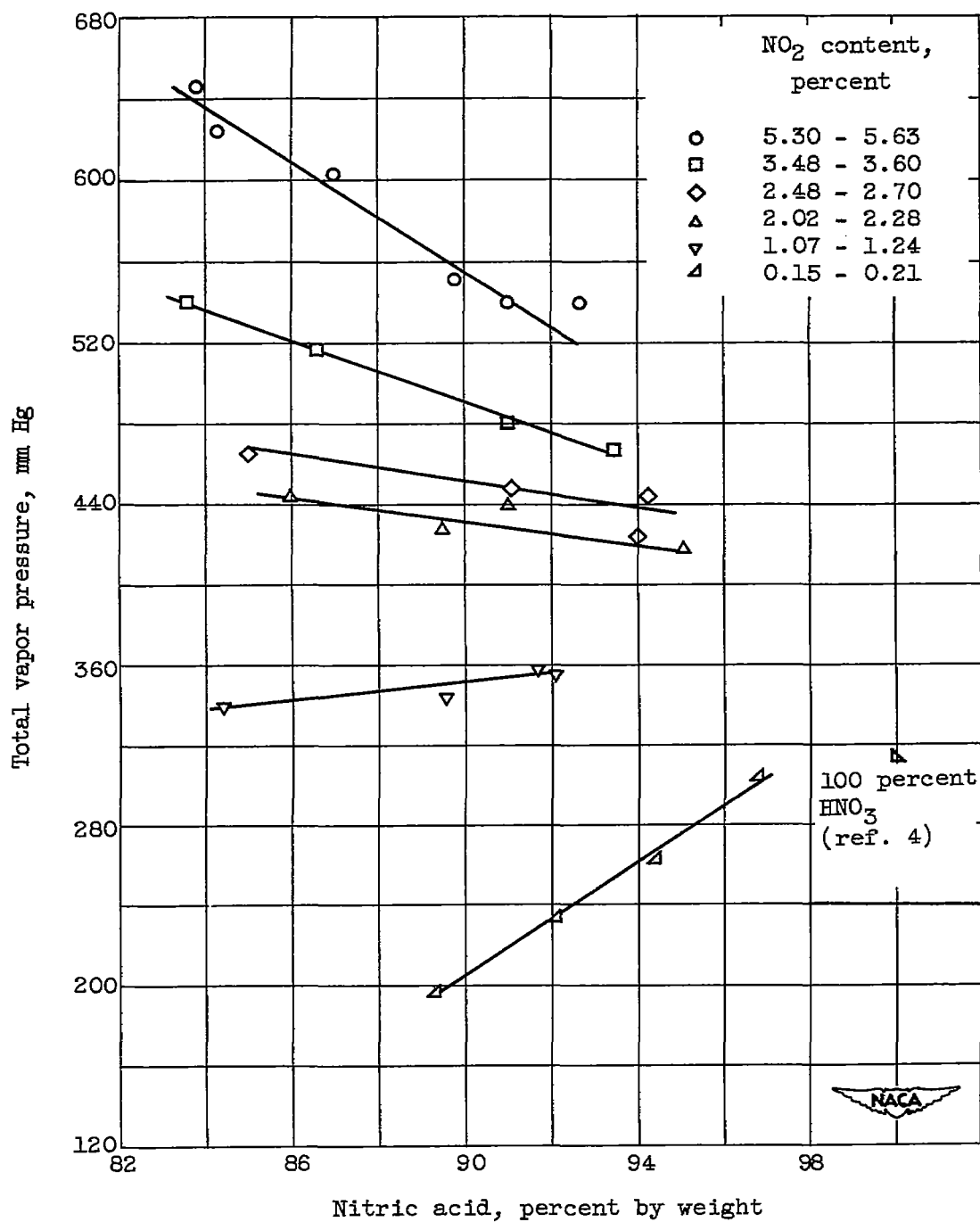
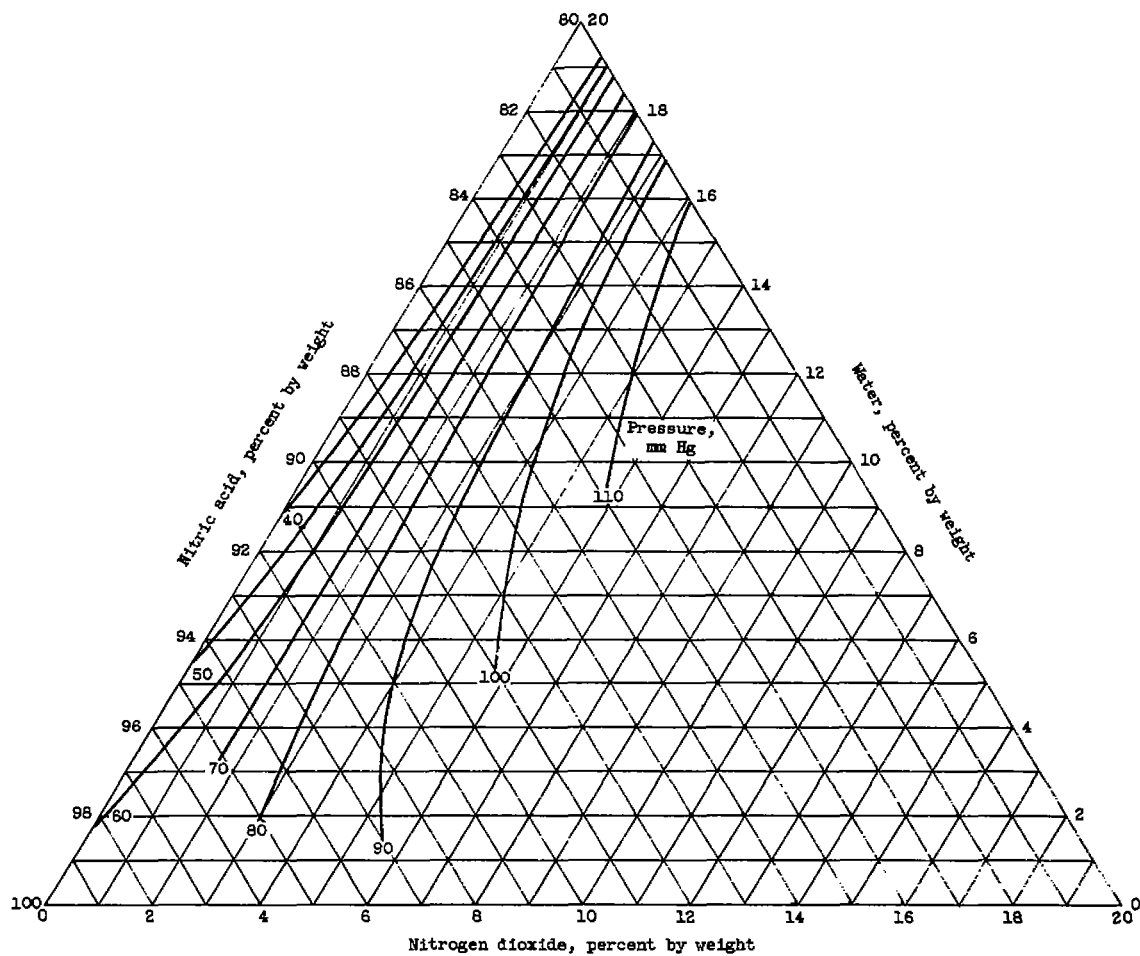


Figure 3. - Concluded. Variation of total vapor pressure of nitric acid solutions with composition. Ullage, 0.65.



(a) Temperature, 25° C.



Figure 4. - Total vapor pressures of the system, nitric acid, nitrogen dioxide, and water.
Ullage, 0.65.

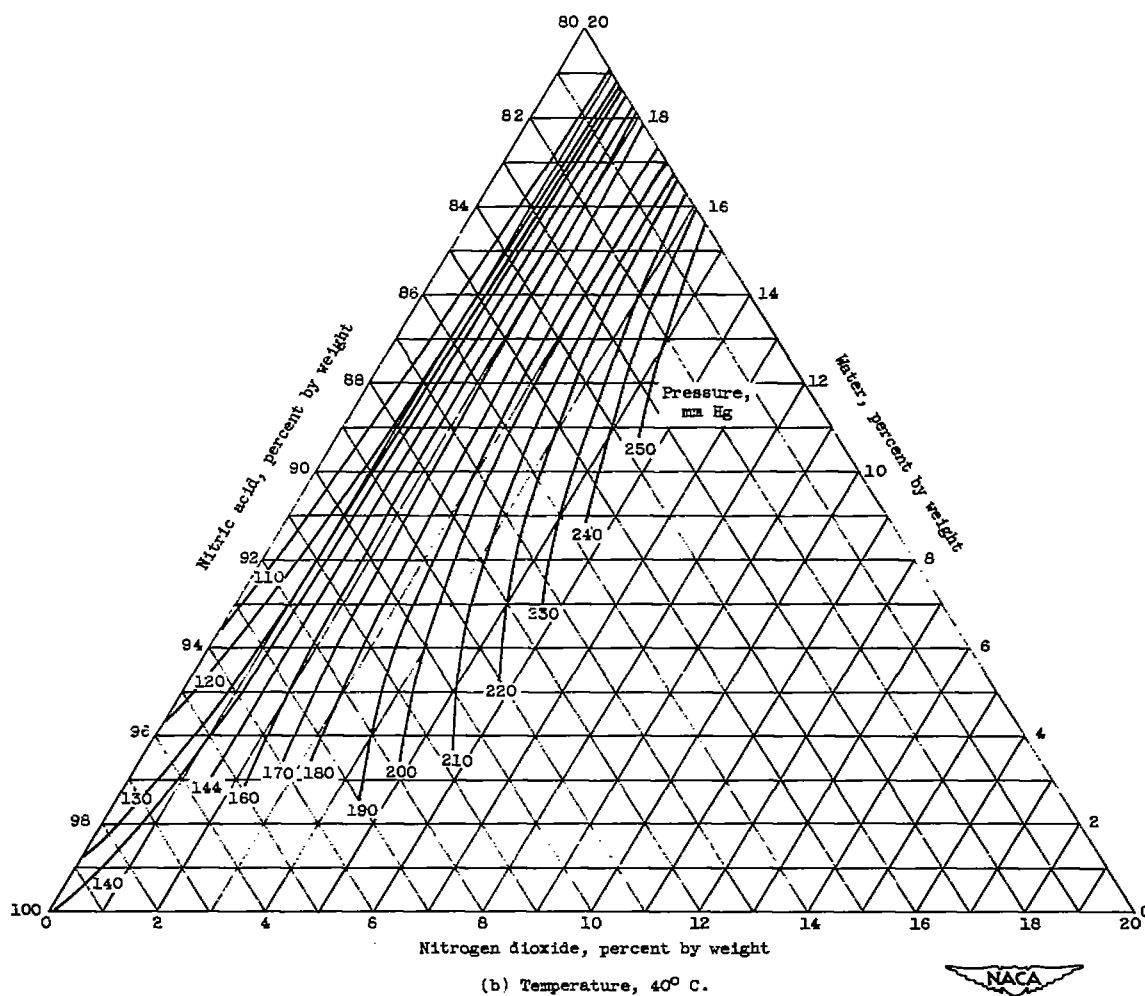


Figure 4. - Continued. Total vapor pressures of the system, nitric acid, nitrogen dioxide, and water.
Ullage, 0.65.

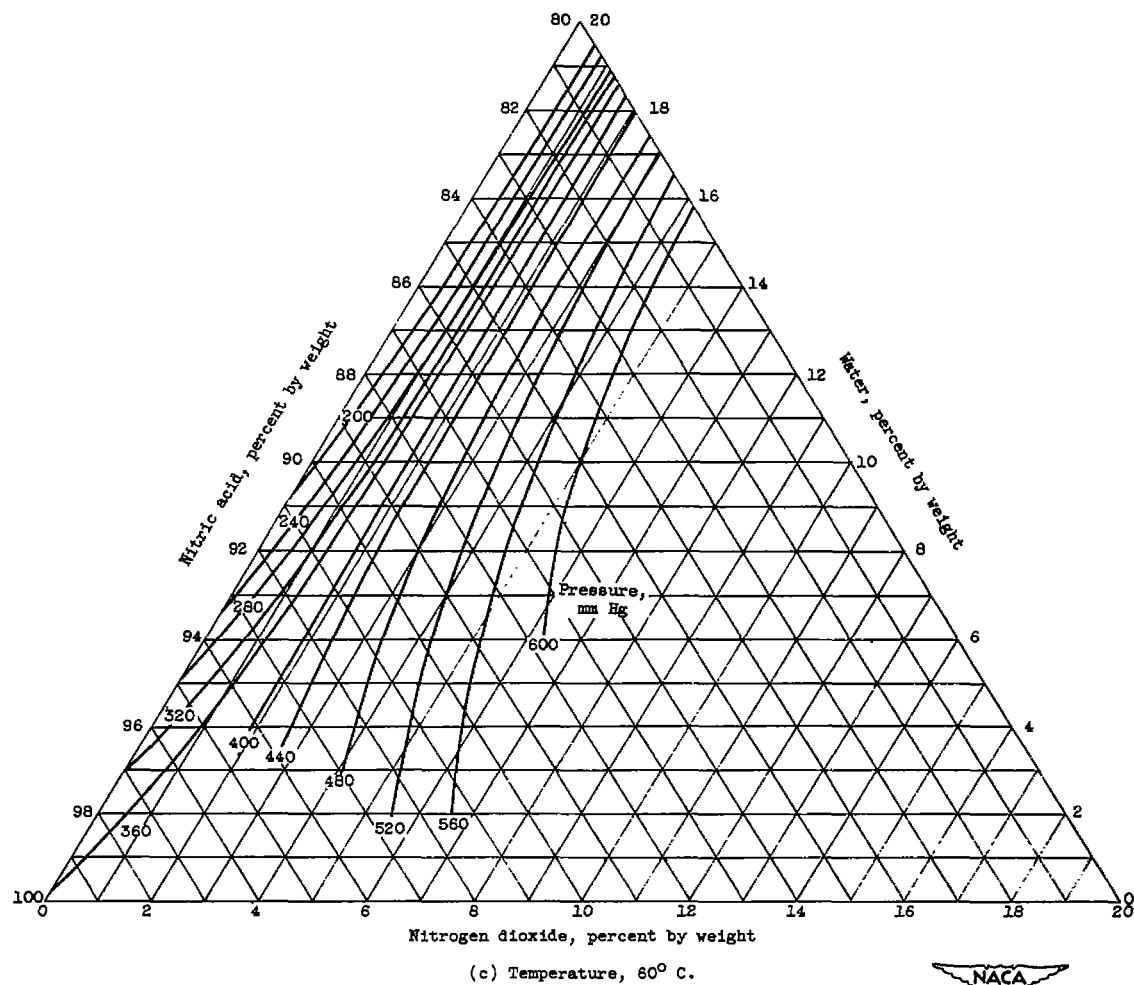


Figure 4. - Concluded. Total vapor pressures of the system, nitric acid, nitrogen dioxide, and water.
Ullage, 0.85.

NASA Technical Library



3 1176 01435 2695